TABLE 1-continued

Sample	Oxygen Permeation Rate ($cc/m^2/day$) 23° C.	38° C.	Water Vapor Permeation ($g/m^2/day$)⁺ 23° C.	38° C.
1-barrier stack with ITO	<0.005	<0.005*	—	0.011⁺
2-barrier stacks	<0.005	<0.005*	—	<0.005⁺
2-barrier stacks with ITO	<0.005	<0.005*	—	<0.005⁺
5-barrier stacks	<0.005	<0.005*	—	<0.005⁺
5-barrier stacks with ITO	<0.005	<0.005*	—	<0.005⁺
DuPont film[1] (PET/Si_3N_4 or PEN/Si_3N_4)	0.3	—	—	—
Polaroid[3]	<1.0	—	—	—
PET/Al[2]	0.6	—	0.17	—
PET/silicon oxide[2]	0.7–1.5	—	0.15–0.9	—
Teijin LCD film (HA grade - TN/STN)[3]	<2	—	<5	—

*38° C., 90% RH, 100% O_2
⁺38° C., 100% RH
[1]P. F. Carcia, 46th International Symposium of the American Vacuum Society, Oct. 1999
[2]Langowski, H. C., 39th Annual Technical Conference Proceedings, SVC, pp. 398–401 (1996)
[3]Technical Data Sheet

As the data in Table 1 shows, the barrier stacks of the present invention provide oxygen and water vapor permeation rates several orders of magnitude better than PET coated with aluminum, silicon oxide, or aluminum oxide. Typical oxygen permeation rates for other barrier coatings range from about 1 to about 0.1 $cc/m^2/day$. The oxygen transmission rate for the barrier stacks of the present invention is less than 0.005 $cc/m^2/day$ at 23° C. and 0% relative humidity, and at 38° C. and 90% relative humidity. The water vapor transmission rate is less than 0.005 $g/m^2/day$ at 38° C. and 100% relative humidity. The actual transmission rates are lower, but cannot be measured with existing equipment.

The barrier assemblies were also tested by encapsulating organic light emitting devices using the barrier stacks of the present invention. The organic light emitting devices are extremely sensitive to water vapor, and they are completely destroyed in the presence of micromole quantities of water vapor. Experimentation and calculations suggest that the water vapor transmission rate through the encapsulation film must be on the order of about 10^{-6} to 10^{-5} $g/m^2/day$ to provide sufficient barrier protection for acceptable device lifetimes. The experiments/calculations are based on the detrimental hydrolysis reaction of water vapor with the extremely thin (less than 10 nm), low work function, cathode materials (Ca, Mg, Li, LiF). Hydrolysis of the cathode leads to the formation of non-conductive reaction products (such as hydroxides and oxides) that delaminate or blister away from the electron transport layers of the organic light emitting devices, resulting in the formation of dark spots on the device.

The organic light emitting devices encapsulated in the barrier stacks of the present invention have been in operation for over six months without measurable degradation. The extrapolated lifetime for the encapsulated devices exceeds the required 10,000 hours necessary to satisfy industry standards. The barrier stacks are extremely effective in preventing oxygen and water penetration to the underlying components, substantially outperforming other thin-film barrier coatings on the market.

The preferred deposition process is compatible with a wide variety of substrates. Because the preferred process involves flash evaporation of a monomer and magnetron sputtering, deposition temperatures are well below 100° C., and stresses in the coating can be minimized. Multilayer coatings can be deposited at high deposition rates. No harsh gases or chemicals are used, and the process can be scaled up to large substrates and wide webs. The barrier properties of the coating can be tailored to the application by controlling the number of layers, the materials, and the layer design. Thus, the present invention provides a barrier stack with the exceptional barrier properties necessary for hermetic sealing of an environmentally sensitive display device, or other environmentally sensitive device. It permits the production of an encapsulated environmentally sensitive display device.

While certain representative embodiments and details have been shown for purposes of illustrating the invention, it will be apparent to those skilled in the art that various changes in the compositions and methods disclosed herein may be made without departing from the scope of the invention, which is defined in the appended claims.

What is claimed is:

1. A barrier assembly comprising:

at least one barrier stack comprising at least one barrier layer and at least one polymer layer, wherein the at least one barrier stack has an oxygen transmission rate of less than 0.005 $cc/m^2/day$ at 23° C. and 0% relative humidity.

2. The barrier assembly of claim **1** wherein the at least one barrier stack has an oxygen transmission rate of less than 0.005 $cc/m^2/day$ at 38° C. and 90% relative humidity.

3. The barrier assembly of claim **1** wherein the at least one barrier stack has a water vapor transmission rate of less than 0.005 $g/m^2/day$ at 38° C. and 100% relative humidity.

4. The barrier assembly of claim **1** further comprising a substrate adjacent to the at least one barrier stack.

5. The barrier assembly of claim **1** wherein the at least one barrier layer is substantially transparent.

6. The barrier assembly of claim **1** wherein at least one of the at least one barrier layer comprises a material selected from metal oxides, metal nitrides, metal carbides, metal oxynitrides, metal oxyborides, and combinations thereof.

7. The barrier assembly of claim **6** wherein the metal oxides are selected from silicon oxide, aluminum oxide, titanium oxide, indium oxide, tin oxide, indium tin oxide, tantalum oxide, zirconium oxide, niobium oxide, and combinations thereof.

8. The barrier assembly of claim **6** wherein the metal nitrides are selected from aluminum nitride, silicon nitride, boron nitride, and combinations thereof.

9. The barrier assembly of claim **6** wherein the metal oxynitrides are selected from aluminum oxynitride, silicon oxynitride, boron oxynitride, and combinations thereof.

10. The barrier assembly of claim **1** wherein the at least one barrier layer is substantially opaque.

11. The barrier assembly of claim **1** wherein at least one of the at least one barrier layers is selected from opaque metals, opaque polymers, opaque ceramics, and opaque cermets.

12. The barrier assembly of claim **4** wherein the substrate comprises a flexible substrate material.

13. The barrier assembly of claim **12** wherein the flexible substrate material is selected from polymers, metals, paper, fabric, and combinations thereof.

14. The barrier assembly of claim **4** wherein the substrate comprises a rigid substrate material.